

# The Carbon Footprint and Cost of Virtual Residency Interviews

Alexander Domingo<sup>1</sup>, MD  
 Justin Singer<sup>2</sup>, MD  
 Adrian Cois<sup>3</sup>, MD  
 Joanna Hatfield<sup>4</sup>, MD  
 Rebecca E. Rdesinski<sup>5</sup>, MSW, MPH  
 Anthony Cheng<sup>6</sup>, MD

Megan Aylor, MD  
 John Sullenbarger, MD  
 Sara Walker<sup>7</sup>, PhD  
 Shane Hervey, BS  
 Amy Stenson<sup>8</sup>, MD, MPH

## ABSTRACT

**Background** The shift from in-person to virtual residency interviews may impact greenhouse gas emissions (GHGE) and costs but the direction and amount of this change is not yet clear.

**Objective** To estimate GHGE and financial impacts of virtual interviews among applicants and programs.

**Methods** In 2020-2021 we sent a postinterview survey to 1429 applicants from 7 residency programs and 1 clinical psychology program at 1 institution. The survey collected origin of travel and transit type if in-person interviews had been held and excluded responses if the applicant would not have participated in an in-person interview, or if travel type or original city was missing. We used the International Civil Aviation Organization calculator to estimate flight-related GHGE in metric tons of carbon dioxide equivalent (MTCO<sub>2e</sub>) and Google Maps to estimate ground travel, with a standard CO<sub>2e</sub> per mile. Flight, hotel, and airport taxi costs were estimated using Expedia.com, Hotels.com, Uber, and Lyft. We aggregated these data and calculated median and interquartile ranges (IQRs) for applicant GHGE and cost savings, and assumed no cost or GHGE from virtual interviews. We used Wilcoxon signed rank sum tests to compare in-person 2019-2020 and virtual 2020-2021 GME program interview budgets.

**Results** The survey response rate was 565, or 40% of applicants; 543 remained after the exclusion criteria were applied. Reduction in applicant travel due to virtual interviews led to median estimated GHGE savings of 0.47 (IQR 0.30-0.61) MTCO<sub>2e</sub> and \$490 (IQR \$392-\$544) per applicant, per interview. Programs savings ranged from \$7,615 to \$33,670 for the interview season.

**Conclusions** Virtual interviews in 8 GME programs were associated with lower estimated GHGE and costs, for applicants and programs, compared with in-person interviews.

## Introduction

The World Health Organization has named climate change “the greatest threat to human health in the 21st century.”<sup>1</sup> Greenhouse gas emissions (GHGE) are the primary driver of climate change, and it is estimated that 8.5% of US national GHGE come from the US health care system.<sup>2</sup> With more than 40 000 US residency applicants annually, and many travelling extensively to interview, virtual residency interviews have the potential to significantly reduce GHGE and costs.<sup>3,4</sup> However, little is known about these impacts.

Several studies have shown reduced GHGE due to virtual residency interviews.<sup>5-8</sup> Few included financial analyses for applicants and programs.<sup>9-11</sup> While results were generally favorable, varying

methodology and a limited number of included programs or geographic regions limit generalizability. No studies have been conducted in the Pacific Northwest.

In this study, we evaluated the impact of virtual interviews on GHGE and cost for applicants from 7 residency programs and 1 clinical psychology program in the 2020-2021 virtual interview cycle at a single institution in the Pacific Northwest.

## Methods

In 2020-2021, applicants to anesthesiology, emergency medicine, family medicine, general surgery, obstetrics and gynecology, pediatrics, and psychiatry residency programs as well as clinical psychology internship and PhD programs at one large academic medical center in the Pacific Northwest were surveyed following their virtual interviews.

The survey was developed by a multidisciplinary group using expert opinion and literature review for content validity. The instrument contains 3 items used

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*Editor's Note: The online version of this article contains the survey used in the study and the geographic distribution of survey respondents and US medical school graduates.*

to estimate carbon emissions savings, including (1) estimated origin of travel (free text field for city, drop down menus for state and country); (2) mode of transport (multiselect with write-in other field); and (3) if the participant would have interviewed at our institution if interviews had been in-person (select yes/no). The survey contained additional items assessing virtual interview format acceptability.<sup>12</sup> We piloted the survey among a group of 10 people including medical students, residents, and faculty to ensure clarity (see online supplementary data). We excluded applicants who did not indicate origin of travel or transit type or reported they would not have interviewed at our institution had interviews been in-person.

### GHGE Estimation

For flight transit, we selected the most direct route from origin city to Portland using Expedia.com and obtained GHGE in metric tons of carbon dioxide equivalent (MTCO<sub>2</sub>e) for each route from the International Civil Aviation Organization online calculator.<sup>13,14</sup> We allotted 30 miles for airport ground travel for applicants selecting flight transit. For applicants who selected exclusively ground travel, we used Google Maps to estimate the most direct travel distances.<sup>15</sup> For alternative transit including biking, walking, light rail, and bus we assigned zero GHGE. For passenger vehicle travel we applied the Environmental Protection Agency estimate for a typical vehicle of 404 grams CO<sub>2</sub> equivalent GHGE per mile.<sup>16</sup> We aggregated these data and calculated medians and interquartile ranges (IQRs) of flight and ground transit GHGE savings (compared with assumed zero GHGE for virtual interview) in MTCO<sub>2</sub>e per interviewee.

### Applicant Cost Estimation

For flight transit we assigned the most economical roundtrip flight (regardless of route or time of day) of those available on Expedia.com in early November 2021. For passenger vehicle airport travel, we assigned the average cost of rides available at 3 different times on Uber and Lyft rideshare services. Non-local applicants were assigned the average cost of available accommodations on Hotels.com in downtown Portland during the same November dates. For applicants reporting passenger vehicle transit, quickest route mileage was collected from Google Maps and multiplied by \$0.18 per mile.<sup>17</sup> No cost was included for alternative transit methods. We aggregated these data and calculated median and IQR cost savings (compared with assumed zero cost of virtual interview) per interviewee.

### Program Cost Calculation

We collected program-specific data on numbers of applications received, interviews performed, learners matched, and actual budgets for interviews conducted in the 2019-2020 and 2020-2021 application cycles. Budget data include direct costs such as interview day meals and materials but not indirect costs (eg, faculty salary). Annual medians by program were compared using Wilcoxon signed rank sum tests.

Statistical tests were conducted using SAS 9.4 software (SAS Institute Inc). This study was declared exempt by the Oregon Health & Science University Institutional Review Board.

### Results

Interview response rate was 40% (565 of 1429). Twenty-two respondents were excluded from analysis (14 for missing travel type, 7 for missing origin city, and 1 for unwilling to interview in-person). Previously reported demographic data<sup>12</sup> demonstrated that more applicants were located in the West (224 of 565, 40%), and few were from international locations (5 of 565, <1%; see online supplementary data).

GHGE savings estimates are shown in TABLE 1. Almost 98% of the GHGE savings were the result of avoided air travel. The median GHGE savings was 0.47 (IQR 0.30-0.61) MTCO<sub>2</sub>e per person. Applicant cost savings are shown in TABLE 1. Median savings for those travelling by air was \$498 (IQR \$428-\$544) per person, inclusive of flight, taxi, and hotel cost. Applicants traveling by ground were primarily local, thus they saved a median of \$1 (IQR \$1-\$168), inclusive of fuel and (if non-local) hotel costs. Overall, applicants saved a median of \$490 (IQR \$392-\$544).

As shown in TABLE 2, the total number of interviews increased by 32%. Although more interviews were conducted, programs reported direct cost savings ranging from \$7,615 to \$33,670, with a total savings of \$124,704 for all 8 programs.

### Discussion

This study found that graduate medical education (GME) applicant virtual interviews appear to reduce travel-associated GHGE and costs for programs and applicants. For applicants included in our analysis, the estimated GHGE savings of 255.71 MTCO<sub>2</sub>e is greater than the annual combined GHGE of 16 Americans<sup>18</sup> or the annual GHG sequestration of 296 acres of forestland.<sup>19</sup> In addition, GME programs saved \$7,615 to \$33,670 on direct interview costs.

TABLE 1

Participant Carbon Emissions and Cost Savings by Mode of Transport

Primary Transit	N (%)	Estimated GHGE in MTCO <sub>2</sub> e			Estimated Cost in \$			
		Flight Median, IQR <sup>a</sup> (Total)	Ground Median, IQR <sup>a</sup> (Total)	Total Median, IQR <sup>a</sup> (Total)	Flight Median, IQR <sup>a</sup> (Total)	Hotel Median, IQR <sup>a</sup> (Total)	Ground Median, IQR <sup>a</sup> (Total)	Total Median, IQR <sup>a</sup> (Total)
Air	476 (87.7)	0.49, 0.3-0.62 (244.02)	0.01, 0.01-0.01 (5.65)	0.50, 0.31-0.63 (249.67)	289, 217-333 (136,461)	136, 136-136 (64,941)	75, 75-75 (34,894)	498, 428-544 (236,296)
Ground	67 (12.3)	<sup>b</sup>	0.00, 0.00-0.14 (6.04)	0.00, 0.00-0.14 (6.04)	<sup>b</sup>	0, 0-136 (3,684)	1, 1-32 (1,346)	1, 1-168 (5,030)
All transit	543 (100)	0.49, 0.30-0.62 (244.02)	0.01, 0.01-0.01 (11.69)	0.47, 0.30-0.61 (255.71)	289, 217-333 (136,461)	136, 136-136 (68,625)	75, 75-75 (36,240)	490, 392-544 (241,326)

Abbreviations: GHGE, greenhouse gas emissions; MTCO<sub>2</sub>e, metric tons of carbon dioxide equivalent; IQR, interquartile range.<sup>a</sup> 25th and 75th percentile IQR.<sup>b</sup> Field not applicable or counted for these applicants.

Other studies have also found potential savings from the move from in-person to virtual interviews, although different methods have been used for analysis.<sup>5-11</sup> Differences include varied transit and accommodation costs, reported versus estimated routes, and diverse geographic locations. However, our estimate of 0.47 MTCO<sub>2</sub>e GHGE savings is similar to other studies with estimates that ranged from 0.18 to 0.70 MTCO<sub>2</sub>e per interview.<sup>5-8</sup> Our estimated \$490 in median cost savings is similar to other reported savings of \$193 (Southwest)<sup>10</sup> and \$566 (Midwest),<sup>9</sup> as well as \$250 to \$499 in a broader survey of 759 applicants.<sup>11</sup>

This study is limited by the response rate, such that respondents may not represent the total population of

applicants. The use of 8 GME programs at one institution limits generalizing the results to other settings. GHGE may have been underestimated due to our use of flights with the shortest distance and fewest connections, and omission of emissions from non-transit sources. Costs may have been underestimated due to selection of flights based on the lowest price and omission of non-transit costs. It is also not clear whether the number of flights (or GHGE savings) would be reduced by the absence of medical student interview travel, or whether the number of flights would remain the same in this time period. Finally, our program cost data do not include indirect costs (eg, faculty productivity), which may be increased due to interview inflation or decreased due to fewer

TABLE 2

Comparison of Numbers of Applicants, Interviewees, Matched Candidates, and Cost Between Virtual and Prior In-Person Interview Seasons

Interview Season Characteristic	Interview Year		P value
	2020-2021	2019-2020	
Number of programs	8	8	
Total number of applicants	8868	8271	
Median number of applicants by program (IQR <sup>a</sup> )	1245 (1058-1715)	1100 (1062-1400)	.13
Total number interviewed	1429	1081	
Median number interviewed by program (IQR <sup>a</sup> )	186 (108-250)	126 (90-174)	.008
Total number matched	96	95	
Total cost of interviews in \$	39,924	164,628	
Median cost of interviews by program in \$ (IQR <sup>a</sup> )	5463 (1,063-7,437)	17,427 (12,900-25,345)	.008
Median cost per intern matched by program in \$ (IQR <sup>a</sup> )	464 (135-658)	1726 (1,002-3,125)	.008

Abbreviation: IQR, interquartile range.

<sup>a</sup> IQR 25th and 75th percentile.

number of interviews, per candidate, conducted virtually.

Future research could focus on confirming applicant carbon footprint and cost savings in various geographic locations or examining the impact of hybrid interview models. Further research is also needed to further specify various components of program cost savings, accounting for direct and indirect costs as well as virtual interview inflation.

## Conclusions

Our results suggest that virtual GME interviews may reduce GHGE while saving on financial costs for residency applicants and programs.

## References

1. IPCC. Sixth Assessment Report. Accessed October 15, 2019. <https://www.ipcc.ch/assessment-report/ar6/>
2. Eckelman MJ, Sherman J. Environmental impacts of the U.S. health care system and effects on public health. *PLoS One*. 2016;11(6):e0157014. doi:10.1371/journal.pone.0157014
3. Association of American Medical Colleges. ERAS Statistics. Accessed February 15, 2022. <https://www.aamc.org/data-reports/interactive-data/eras-statistics-data>
4. Lessons From The 2021 Residency Match. *The Hospital Medical Director*. Published March 23, 2021. Accessed February 15, 2022. <https://hospitalmedicaldirector.com/lessons-from-the-2021-residency-match/>
5. Donahue LM, Morgan HK, Peterson WJ, Williams JA. The carbon footprint of residency interview travel. *J Grad Med Educ*. 2021;13(1):89-94. doi:10.4300/JGME-D-20-00418.1
6. Bernstein D, Beshar I. The carbon footprint of residency interviews. *Acad Med*. 2021;96(7):932. doi:10.1097/ACM.0000000000004096
7. Liang KE, Dawson JQ, Stoian MD, Clark DG, Wynes S, Donner SD. A carbon footprint study of the Canadian medical residency interview tour. *Med Teach*. 2021;43(11):1302-1308. doi:10.1080/0142159X.2021.1944612
8. Fung B, Raiche I, Lamb T, Gawad N, MacNeill A, Moloo H. A chance for reform: the environmental impact of travel for general surgery residency interviews. *Can Med Educ J*. 2021;12(3):8-18. doi:10.36834/cmej.71022
9. Edje L, Miller C, Kiefer J, Oram D. Using Skype as an alternative for residency selection interviews. *J Grad Med Educ*. 2013;5(3):503-505. doi:10.4300/JGME-D-12-00152.1
10. Shah SK, Arora S, Skipper B, Kalishman S, Timm TC, Smith AY. Randomized evaluation of a web based interview process for urology resident selection. *J Urol*. 2012;187(4):1380-1384. doi:10.1016/j.juro.2011.11.108
11. Fogel HA, Liskutin TE, Wu K, Nystrom L, Martin B, Schiff A. The economic burden of residency interviews on applicants. *Iowa Orthop J*. 2018;38:9-15.
12. Domingo A, Rdesinski R, Stenson A, et al. Virtual residency interviews: applicant perceptions regarding virtual interview effectiveness, advantages, and barriers. *J Grad Med Educ*. 2022;14(2):224-228. doi:10.4300/JGME-D-21-00675.1
13. Expedia Travel: Vacation Homes, Hotels, Car Rentals, Flights & More. Accessed April 14, 2021. <https://www.expedia.com/>
14. ICAO Carbon Emissions Calculator. Accessed April 14, 2021. <https://www.icao.int/environmental-protection/Carbonoffset/Pages/default.aspx>
15. Google Maps. Accessed April 14, 2021. <https://www.google.com/maps>
16. United States Environmental Protection Agency. Greenhouse Gas Emissions from a Typical Passenger Vehicle. Published January 12, 2016. Accessed March 30, 2021. <https://www.epa.gov/greenvehicles/greenhouse-gas-emissions-typical-passenger-vehicle>
17. AAA. Your driving costs. Accessed February 15, 2022. <https://newsroom.aaa.com/wp-content/uploads/2020/12/2020-Your-Driving-Costs-Brochure-Interactive-FINAL-12-9-20.pdf>
18. The World Bank. CO2 Emissions (Metric Tons per Capita) - United States. Accessed February 18, 2022. <https://data.worldbank.org/indicator/EN.ATM.CO2E.PC?locations=US>
19. Domke GM, Oswalt SN, Walters BF, Morin RS. Tree planting has the potential to increase carbon sequestration capacity of forests in the United States. *Proc Natl Acad Sci U S A*. 2020;117(40):24649-24651. doi:10.1073/pnas.2010840117



All authors are with the Oregon Health & Science University School of Medicine. **Alexander Domingo, MD**, is Assistant Professor, Family Medicine; **Justin Singer, MD**, is a PGY-4 Resident, Obstetrics and Gynecology; **Adrian Cois, MD**, is a PGY-3 Resident, Emergency Medicine; **Joanna Hatfield, MD**, is Associate Professor of Obstetrics and Gynecology; **Rebecca E. Rdesinski, MSW, MPH**, is Senior Research Associate, Family Medicine; **Anthony Cheng, MD**, is Assistant Professor of Family Medicine; **Megan Aylor, MD**, is Program Director and Associate Professor of Pediatrics, Division of Pediatric Hospital Medicine; **John Sullenbarger, MD**, is a PGY-3 Resident, Psychiatry; **Sara Walker, PhD**, is Associate Professor of Psychiatry; **Shane Hervey, BS**, is a Fourth-Year Medical Student; and **Amy Stenson, MD, MPH**, is Program Director, Vice Chair of Education, and Associate Professor of Obstetrics and Gynecology.

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## BRIEF REPORT

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Corresponding author: Alexander Domingo, MD, Oregon Health & Science University, [domingoa@ohsu.edu](mailto:domingoa@ohsu.edu), Twitter @alexdomingo

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